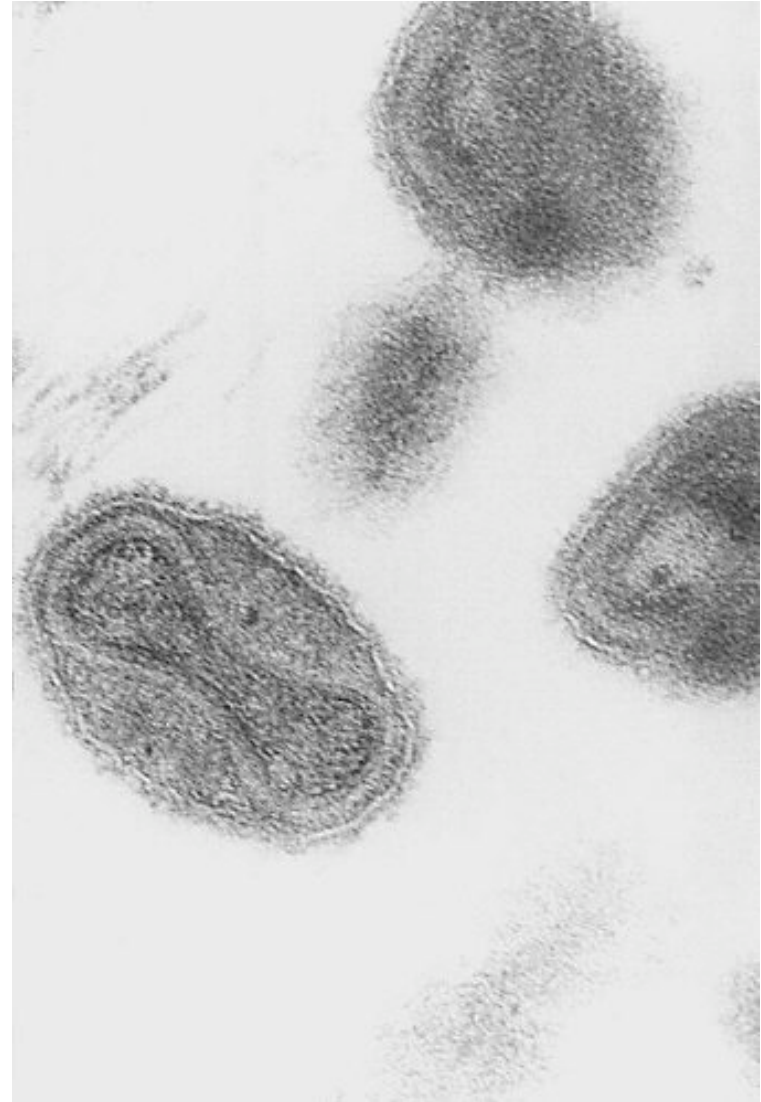




Was Smallpox Airborne? Implications for Biodefense



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Smallpox Transmission

- The threat of epidemic spread posed by a smallpox attack would be substantially greater if smallpox was frequently transmitted from person-to-person by airborne droplet nuclei rather than by large droplets or scabs.
- Expert opinion is divided on whether airborne transmission was the norm.



Smallpox as a Biological Weapon

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Smallpox spreads from person to person,^{10,14} primarily by droplet nuclei or aerosols expelled from the oropharynx of infected persons and by direct contact. Contaminated clothing or bed linens can also spread the virus.¹⁵ There are no known animal or insect reservoirs or vectors.

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SMALLPOX

SMALLPOX FACT SHEET

Smallpox Overview

Transmission

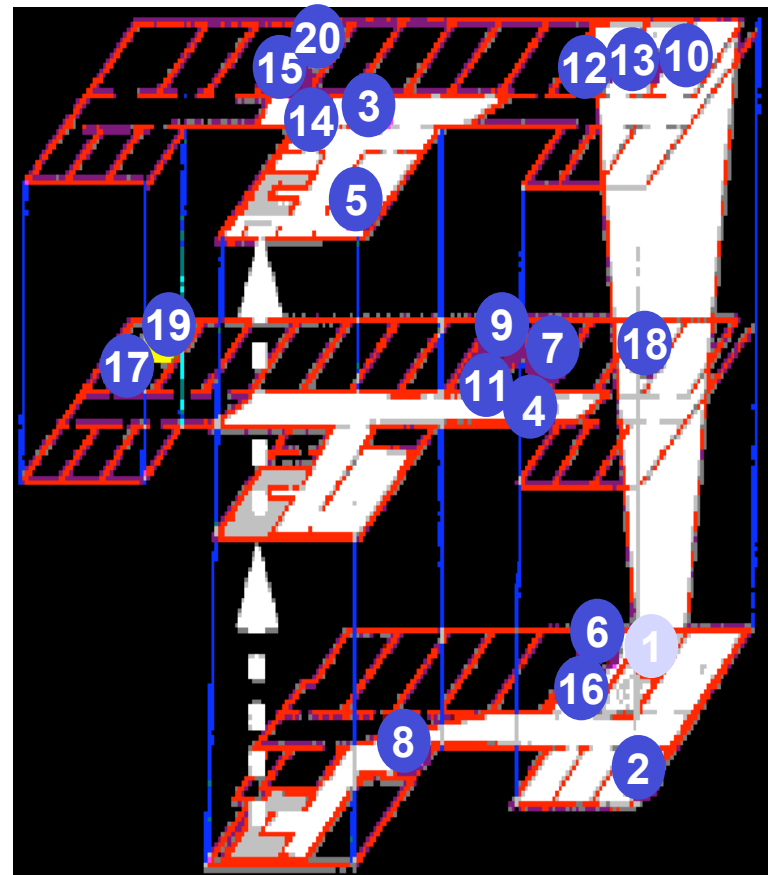
Generally, direct and fairly prolonged face-to-face contact is required to spread smallpox from one person to another. Smallpox also can be spread through direct contact with infected bodily fluids or contaminated objects such as bedding or clothing. Rarely, smallpox has been spread by virus carried in the air in enclosed settings such as buildings, buses, and trains. Humans are the only natural hosts of variola. Smallpox is not known to be transmitted by insects or animals.

<http://www.bt.cdc.gov/agent/smallpox/overview/disease-facts.asp>, Accessed 2/25/2003



Airborne Dispersal of Smallpox

- 1971 outbreak in German hospital
- 1 smallpox patient with cough
- 19 secondary cases over 3 floors



Mod. from Maj M.R. Bell, USUHS, Bethesda, MD



What is the Evidence?

- The Meschede, Germany outbreak in 1970 demonstrated that smallpox could be airborne at least sometimes.
- The question is: was airborne infection the exception or the rule?



Review of Pertinent Evidence

- Variolation
- Asymptomatic mucosal infection
- Oropharyngeal excretion and infectiousness
- Airborne poxvirus measurements
- Animal models
- “Smallpox Handler’s Lung”
- Outbreak Reports and Epidemiology



The Reason Jenner Could Ethically Inoculate James Phipps with Smallpox After Vaccination

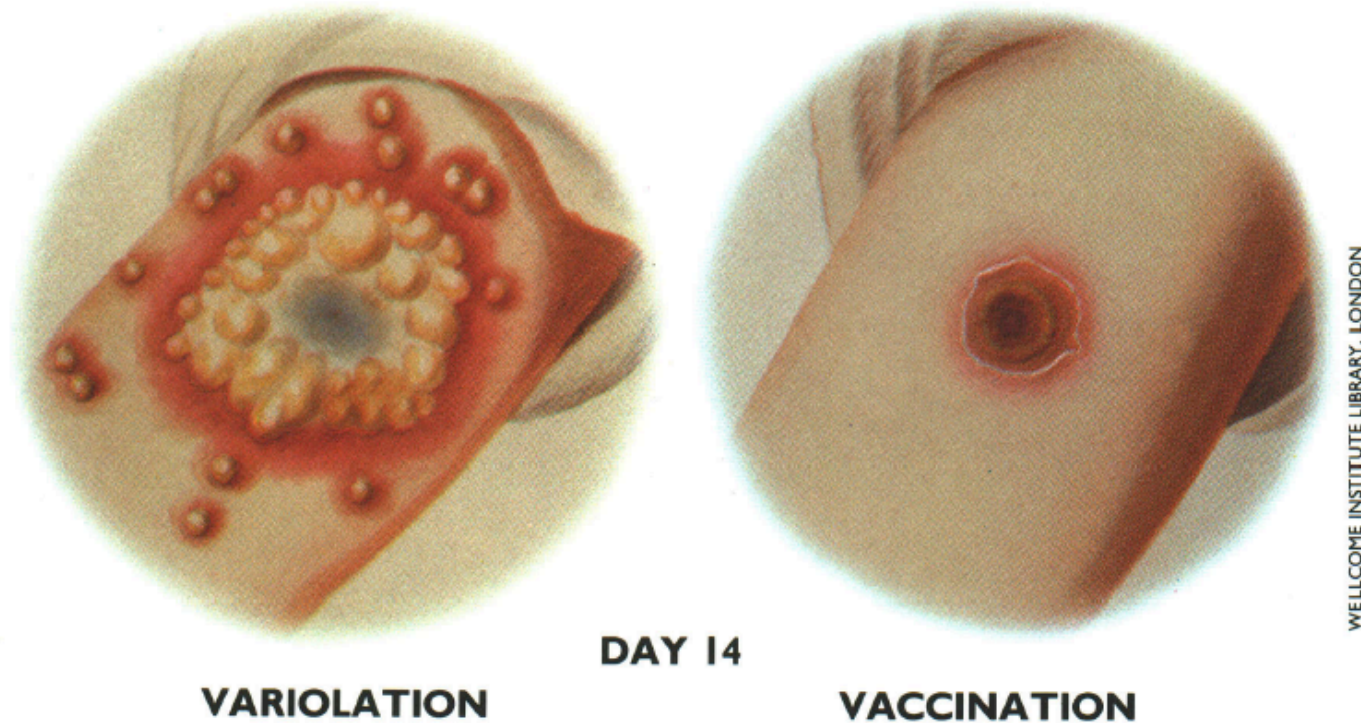


Plate 6.3. The Gold-Kirtland drawings. Variolation and vaccination on the 13th and 14th days after inoculation.



Insufflation of Powdered Smallpox Scabs by the Intranasal Route

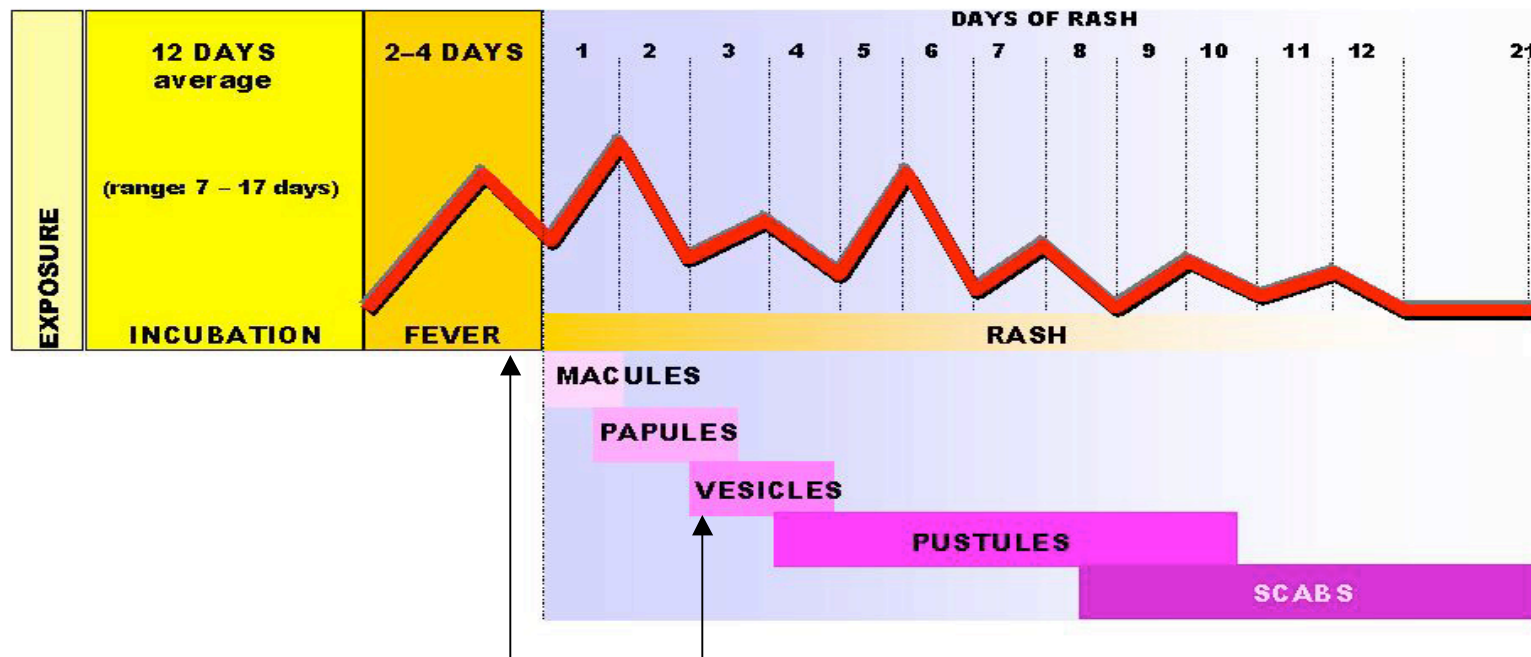


LEDERLE LABORATORIES



Infectiousness and Oral Eruption

The fever and stages of development of the rash in a typical smallpox case



Oral Lesions Erupt

Diagnosis of First Cases

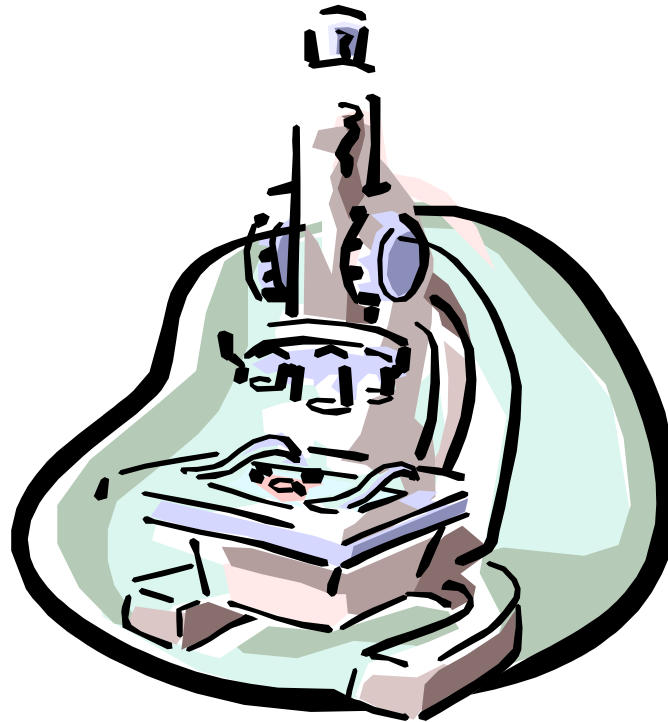


Period Of Infectiousness



Why Were Scabs Not Infectious?

- Large particle size prevented deposition in lower respiratory tract.





Fomites: Not A Contradiction

- Were heavily contaminated with dried respiratory droplets as well as scabs.
- Reaerosolization of respirable particles from surfaces is inefficient, but
- Inhalation anthrax in postal customers shows that reaerosolization of respirable infectious particles can occur.



Close Contact?

- 85% of cases had known close contact with previous case.
- But, most cases stayed home in buildings without mechanical ventilation.
- Exposure to infected exhaled breath only occurred by spending time in the patient's room.



Close Contact?

- If exposure to 1 pfu of airborne variola = 63% probability of infection (ID_{63})
- If average concentration in patient's room = 0.5 to 5 pfu/m³
- Exposure time required for 63% probability of infection = 25 to 250 min.
- Thus, airborne infection consistent with 85% having known contact.



Weight of the Evidence?

- Airborne infection did occur.
- Skin and mucosal infection produced mild disease in humans and animals
- Variola was recovered from exhaled breath
- Smallpox handler's lung implies high concentrations of airborne virus in smallpox hospitals.
- Epidemiology is consistent with airborne infection as the norm not the exception.



Implications?

- Hospitals were the locus of more than 50% of secondary transmission of reintroduced smallpox in Europe between 1950-71.
- How would airborne infection propagate in a hospital?



Modeling Smallpox

- Aerobiological models allow examination of transmission in specific high risk environments, and evaluation prevention by sanitation as well as vaccination.
- Wells-Riley equation developed for measles in schools and applied successfully to tuberculosis in buildings with recirculated air.



Hospital Model

- 150 beds (assumed filled)
- 50 staff x 3 shifts
- 80% of staff preemptively immunized
- 0%, 50%, or 80% of patients immunized.
- Ventilation air changes per hour: 2 (historical), 5 (current standards)
- Infectious dose generation rate based on historical air sampling data from humans and rabbits (range 0.5 to 5/minute).

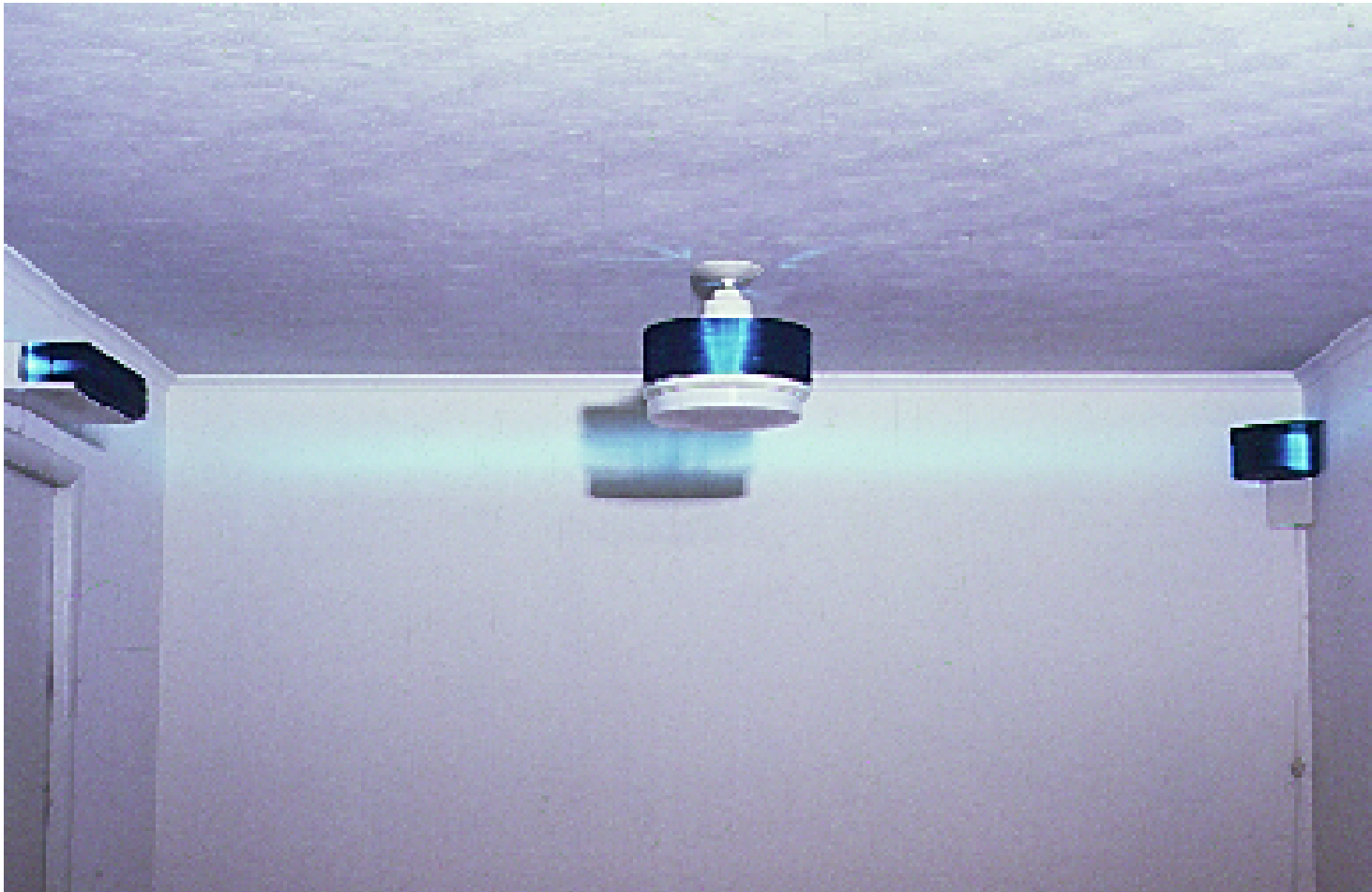


Intervention Models

- Additional air changes from use of UV lights 20 (currently feasible), 100 (possible if variola highly sensitive and engineering optimized).
- One case (historical model)
- Twenty cases (post attack)
- Assume first cases not diagnosed and not isolated for first 48 hours in hospital while infectious.



Germicidal UV fixtures (louvered)





Hospital Transmission: One Case

80% of Patients Immune

Air Changes per Hour

**Immune
Patients**

80%

q (min^{-1})

2

5

20

100

0.5

2

1

0

0

1.0

4

2

0

0

5.0

18

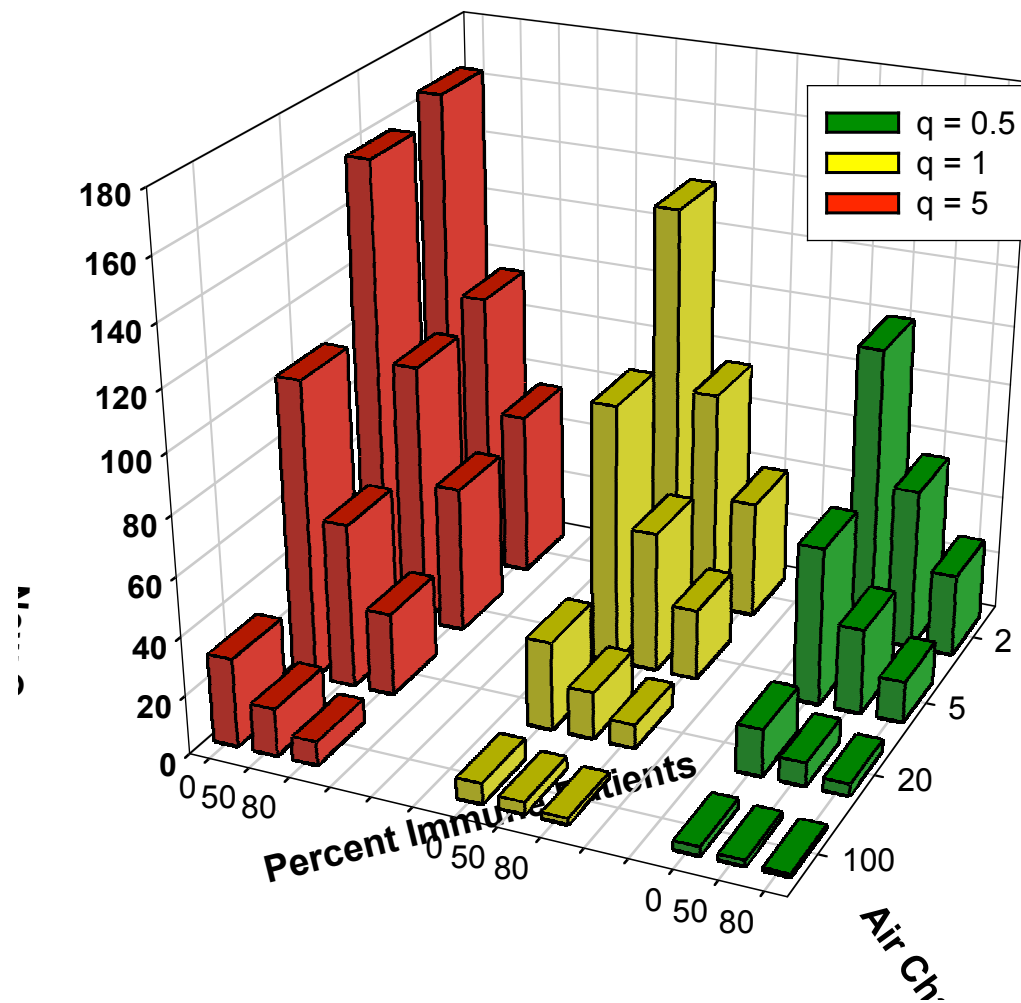
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Hospital Transmission by 20 Undiagnosed Cases





Limitations

- Airborne infectious dose generation rate of smallpox patients early in the disease is not known.
- Staff, as well as patients, are unlikely to be highly immunized so that these estimates may be too low.
- UV effectiveness not known – more work needed (but funding is not available).



Sanitation or Vaccination?

- Hospitals would be a major locus of secondary spread in the event of an attack with smallpox.
- 50% preemptive immunization of the entire population would prevent 46% of hospital acquired cases.
- UV, using current technology, could prevent 66% of cases – without preemptive vaccination.



Conclusions

- The weight of evidence points to airborne transmission as the norm not the exception in smallpox
- Airborne transmission in hospitals would be a severe problem.
- Air sanitation may be an effective alternative or adjunct to vaccination
- Airborne transmission is too important to be ignored.